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RESEARCH ARTICLE

ACCELERATED ORTHODONTIC TREATMENT TECHNIQUES-A REVIEW

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ABSTRACT

There is an increased tendency for researchers to focus on accelerating methods for tooth movement due to the huge demand by adults for a shorter orthodontic treatment time. Unfortunately, adults typically require longer treatment periods because their metabolism is much slower than in younger patients. Probably the best way to shorten treatment time is to speed up tooth movement. Long orthodontic treatment time poses several disadvantages like higher predisposition to caries, gingival recession, and root resorption, decreased patient cooperation. Thus the need for shorter treatment durations with effective treatments has brought about the use of various modalities to accelerate tooth movement .

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INTRODUCTION

The dream of a beautiful smile is currently not difficult to fulfil, as interdisciplinary treatment involving prosthetic, surgical, periodontal, and orthodontic procedures makes successful aesthetic effects possible in the majority of cases. The most important and concerning factor about orthodontic therapy is the duration of the treatment. Various techniques have been established over the years to decrease the treatment duration. Minimally invasive techniques which reduce treatment timing has gained popularity in recent times. Other than the fact that prolonged treatment time causes inconvenience to the patient it also possesses several disadvantages like a higher predisposition to caries, gingival recession and root resorption.

Mechanism of acceleration of tooth movement: Orthodontic force induces a cellular response in the periodontal ligament, which brings about boneresorption on the pressure side and bone deposition on the tension side. This happens via induction of via the RANK-RANKL pathway and presence of various inflammatory mediators such as IL-1, IL-8, TNF-alpha etc.

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Orthodontic movement can be controlled by the size of the applied force and the biological responses from the periodontal ligament. This orthodontic force would cause inflammation around the periodontal ligament due to changes in blood flow, leading to the secretion of different inflammatory mediators like colony-stimulating factors, cytokines, growth factor, arachidonic acid metabolites and neurotransmitters. Macrophage colony stimulating factor (M-CSF), Receptor activator of nuclear factor kappa B ligand (RANKL), and osteoprotegerin (OPG) by osteoblasts play key roles in toot movement. RANKLbinds to its receptor, RANK (Receptor activator of nuclear factor kappa B),on the surface of osteoclastic cells at developmental stage. The RANKL/RANK binding is very critical for the function, differentiation, and survival of osteoclasts.

RAP Phenomenon: Frost discovered the regional acceleratory phenomenon (RAP), and in 1994 Yaffe et al. introduced this concept to periodontal literature . Small harmful stimuli (such as shallow bone incisions) activate the RANK/RANKL system. In "weakened" bone tissue, 10–50 times faster remodelling is expected. This effect lasts for about 4 months (though it can last up to 6–24 months), with peak efficiency reached 1 or 2 months after surgery.91 Due to the nature of the surgery, which involves a high risk of infection, antibiotic protection is vital. To avoid interfering with the bone remodelling process, non-steroidal anti-inflammatory drugs (NSAIDs) should not be administered. Initially (in the first 3–7 days) the pain can severely affect the patient's well-being.

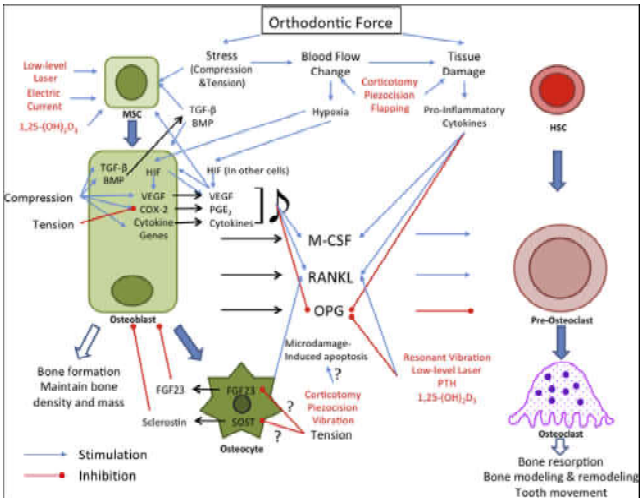


Fig. 1. Effect of orthodontic force on tooth movement

The regional acceleratory phenomenon (RAP) – aphenomenondescribed by H. Frost in 1983, involving the temporary reduction of bone density as a result of harmful stimulus.

- The release of pro-inflammatory cytokines activating osteoclast progenitor cells as a result of harmful stimuli.
- Bone resorption caused by the action of mature osteoclasts. Bone density decreases by 10–50 times, making tissue much more susceptible to the action of orthodontic forces.
- Arrangement of the resorbed tissue by macrophages.
- The inflow of osteoblasts. Bone remineralization with teeth in new positions after 4 months

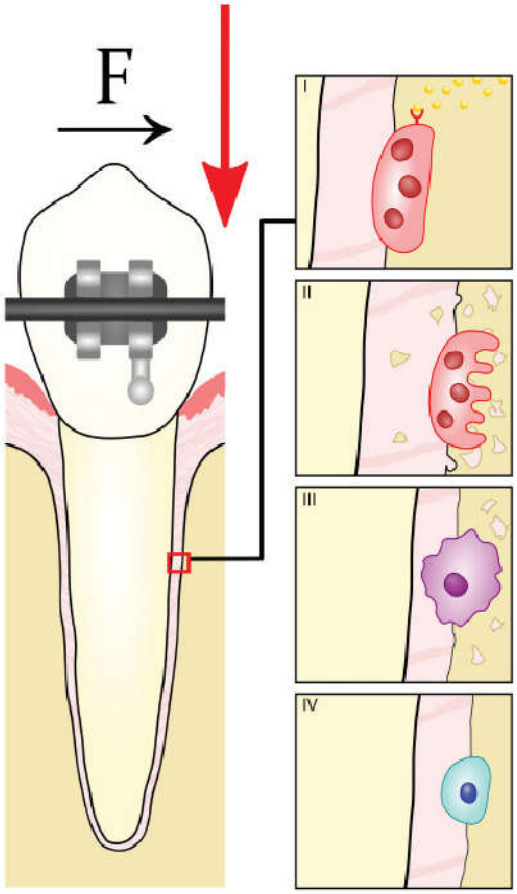


Fig. 2. RAP phenomenon

Methods of accelerating tooth movement: Methods of accelerating tooth movement can be classified into the following techniques

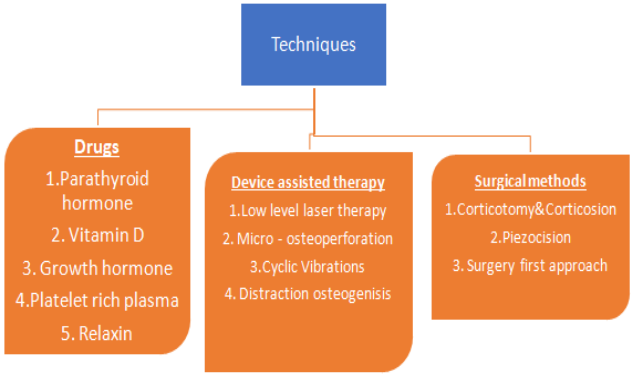


Fig. 3. Classification of Accelerated orthodontic treatment techniques

DRUGS

Parathyroid Hormone: Parathormone (PTH) is a compound secreted by the parathyroid gland which binds to receptors on osteoblasts, activating them and leading to the expression of insulin-like growth factor 1 (IGF-1; somatomedin). This results in the proliferation of osteoblasts and, with the participation of the RANK ligand, osteoclast activation. Depending on the frequency of administration, PTH may stimulate bone formation (intermittent therapy) or its resorption (exposure longer than 1–2 years).Two 12-day studies in rats confirmed that intermittent administration of PTH accelerated the mesialization of the 1st molar 1.6 times after administration of a dose of 0.25 µg/100 g body weight into the subperiosteal area and 1.4 times as a result of subcutaneous administration of 4 µg/100 g m.c. However, another study by the same authors does not confirm the efficacy of intermittent therapy. Long-term research on the superiority of this method over other protocols is needed, as well as clinical trials. Nevertheless, it is important to consider chronic PTH intake when planning orthodontic treatment, e.g., in cases of severe osteoporosis.

Vitamin D: Another agent that may affect tooth movement is vitamin D. 1,25-dihydroxycholecalciferol is the most active metabolite of this vitamin. It mainly has an anabolic effect on the bone tissue (to a small extent also catabolic). Similarly, to PTH, sub-periosteal administration of vitamin D enhances the activity and proliferation of osteoblasts. These properties prompted researchers to design animal experiments attemptingto modify the course of orthodontic treatment. Collinset al. used calcitriol dissolved in DMSO (dimethyl sulfoxide)− a compound that readily penetrates cell membranes, as well as has a high solubility coefficient for vitamin D) − administered daily into the periosteum. After 3 weeks, the retraction range of the canines was 60% higher compared to the control group. Other researchers came to similar conclusions, this time testing the action of this vitamin on rats. They noticed an increased number of both osteoclasts and osteoblasts. After a daily oral dose of 0.25 µg of vitamin D, the mean difference in the retraction movement between the experimental group and the control group (who underwent orthodontic therapy without supplementation) was 1 mm/60 days. However, the use of a very low dose of the supplement in the study appears to be questionable (10 IU vs the daily recommendations of 1000–2000 IU).

Growth hormone: Growth hormone (GH), also called somatotropin, is secreted by the anterior lobe of the pituitary gland. It has a stimulating effect on bone growth and remodelling, and a deficiency results in pituitary dwarfism.

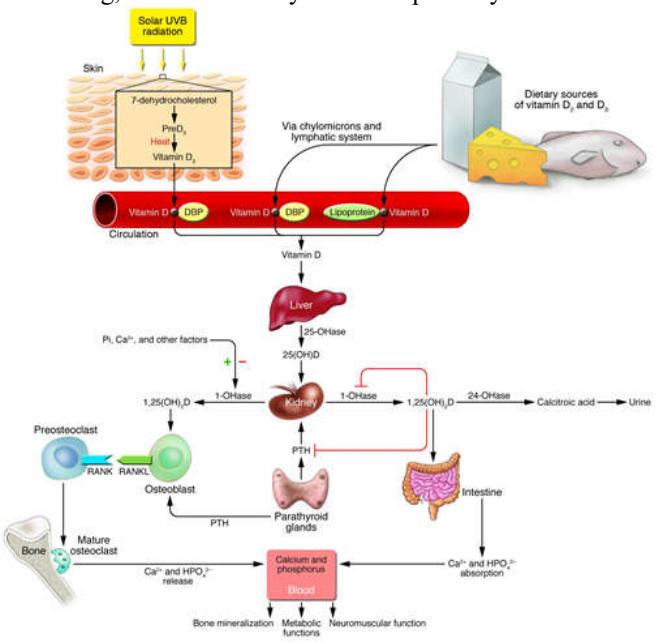
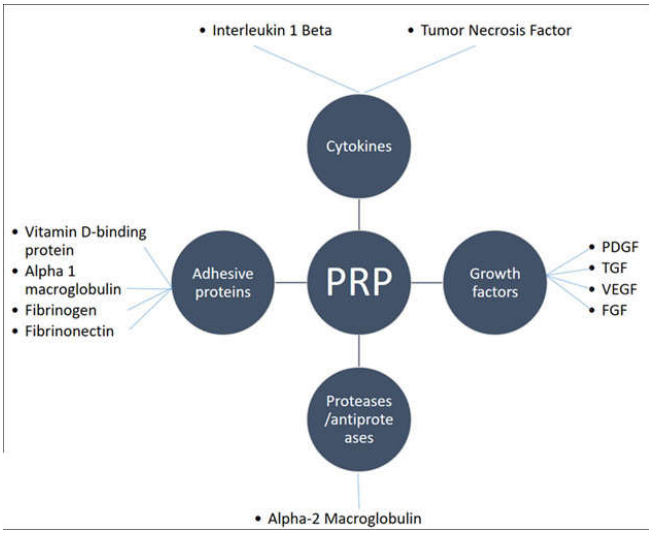


Fig. 4. Vitamin D metabolism

The action of GH is based directly on increase in the proliferation and differentiation of osteoblasts, as well as on induction of protein synthesis and mineralization. Ribeiro et al. assessed the modifying effect of growth hormone on the pace of tooth movement during experimental orthodontic treatment in rats. In their study, individuals from the experimental group were administered daily subcutaneous doses of growth hormone of ≈ 0.033 mg/kg, analogous to the dose used in humans. A day after the 1st dose was administered, a nickel-titanium spring was fixed between the incisor and the right 1st molar, exerting a force of 30 g. Growth hormone accelerated bone resorption (in the experimental group the highest number of osteoclasts was recorded as early as on the 3rd day, which was twice as high as in the control group on day 7), but it also delayed angiogenesis. This suggested that the activation of a device should be less frequent after GH administration. There are even recommendations to begin orthodontic therapy 12–24 months after GH administration, because only then will somatotropin stimulate the process of bone formation. As GH reduces the synchronization between resorption and bone apposition, this is not a method of high potential clinical relevancy.

Platelet Rich Plasma: Peripheral blood contains 94% of red blood cells (RBCs), 6% of platelets, and <1% of white blood cells (WBCs), while PRP contains 5% of RBCs, 1% of WBC, and 94% of platelets. PRPhas been applied in dentistry for its capability of enhancing osseointegration of a dental implant and augmentation of alveolar bone height in maxillary sinus lift a suitable PRP for orthodontic purposes should be inject able and has a long-lasting effect. To develop an inject able PRP with a prolonged effect on the target tissue, a simple approach is to prepare the PRP without mixing with Calcium chloride and thrombin, so that it can be maintained in a liquid form and be inject table. A single injection of PRP lasts for 5–6 months clinically. It has been observed clinically that the fastest rate of acceleration is during the second to fourth month after the injection. The submucosal injection of PRP is a clinically feasible and effective technique to accelerate orthodontic tooth movement and at the same time, preserve the alveolar bone on the pressure side of orthodontictooth movement, and the optimal dose of PRP for the best clinical performance is 11.0–12.5 folds.



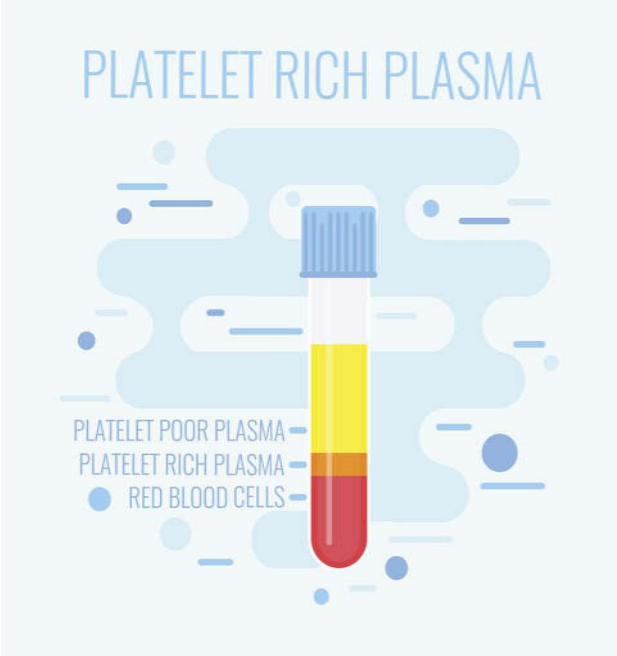


Fig. 5. Platelet rich plasma

Relaxin: Relaxin is a hormone which helps widening of the pubic ligaments in females during delivery; similarly, the presence of this hormone in cranial suture and PDL has been demonstrated. The role of relaxin is known for the remodelling of soft tissue rather than bone. Relaxin has the effect of increasing collagen at tension site and decreasing at pressure site. Experimental studies were performed on animal models and the authors concluded that the human relax in may not accelerate orthodontic tooth movement in rats; it can reduce the level of PDL, reduce the mechanical strength of PDL, and increase mobility of the tooth at early time points. Mc Gorray and co-workers in their clinical trial found local doses of relax in might have been too low to affect tooth movement or short-term relapse.

Beta -2 adrenergic agonists: There is a very specific periodontal microenvironment between the tooth and the bone that requires further description. It consists of collagen fibres, cells and tissue fluid acting as a force absorber. The ligaments are strongly innervated: they contribute to the transmission of pain, modification of the immune response and bone remodelling. During orthodontic treatment mechanical force acting on the tooth is transmitted to these ligaments. Periodontal cells stimulate the biological response (e.g., by increasing the amount of Y-neuropeptide-containing fibre, substance P or calcitonin gene-related peptide).This is confirmed by the impossibility of moving ankylotic teeth, which are deprived of periodontal fibres due to direct connection with the bone. Periodontal ligaments are formed from the cranial neural crest differentiating inembryonic stem cells. Due to their origins, they express β2-adrenergic receptors and, through the RANK receptor system, stimulate osteoblasts to undergo osteoclastogenesis. The available studies involving β2-adrenergic agonists are based on direct evidence (stimulation of receptors with agonists, e.g., isoproterenol) or indirect observations (similar inhibition of the sympathetic system after using propranolol).

DEVICE ASSISTED THERAPY

Photo biomodulation: This technique can be characterized by a very limited invasiveness. It involves the exposure of tissues to the effects of red light of a therapeutic wavelength (600–1200 nm). These wavelengths reduce absorption of the light by haemoglobin and water and allow it to reach the deeper soft tissue and the alveolar bone. The resulting stimulation may have potentially positive effects on the production of adenosine triphosphate (ATP). On the other hand, increasing the activity of cells leads to increased bone metabolism in situ, which creates favourable conditions for the movement of teeth. Therapy with light can be divided into 2 basic types: low-intensity lasers (LIL), producing coherent light, and light-emitting diodes (LED), which are sources of incoherent light. Most authors agree that the cellular response depends primarily on the wavelength and the dose of light. Most studies indicate a significant increase in the rate of tooth movement. In these studies, gallium-aluminium-arsenide (Ga-Al-As) lasers were used, and the length of light wave was on average 820 nm.

Fig. 6. Photobiomodulation

Micro-osteoperforation: This is considered the least invasive treatment modality using the RAP phenomenon. The goal is to further minimize soft tissue damage. Perforations are made in the bone through the mucous membrane, with the aim of accelerating orthodontic movement. Micro-osteoperforations can also be combined with standard corticotomy or the PAOO technique. The device used during the treatment was designed by Propel Orthodontics (Ossing, USA). It is intended for single use only. It perforates both the attached gingiva and the mucous membrane. Clinically, the use of micro-osteoperforations significantly increases the expression of cytokines, which leads to a 60% shorter treatment time compared to a control group, and 2.3 times faster retraction of canines. The procedure itself is described as effective, convenient, and less invasive than standard corticotomy.

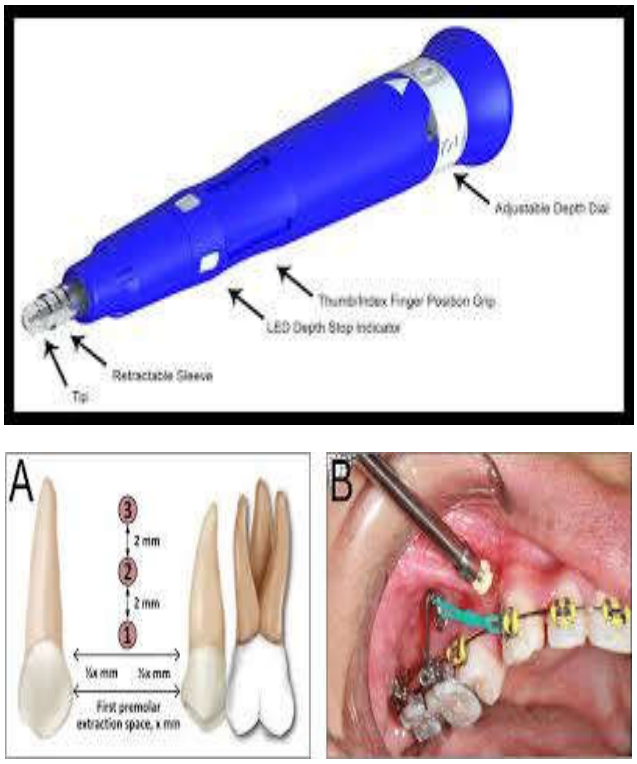


Fig. 7. Micro-osteoperforation

Corticotomy and other attempts at surgical acceleration of tooth movement are documented in a large number of scientific publications. Despite the different levels of invasiveness, they have similar effectiveness,

Cyclic Vibrations: The use of cyclic vibratory method is to place light alternating forces on the teeth via mechanical radiations. The initial response of cells to mechanical stress in vitro appears within 30 minutes. Signals from the force sensor and the accelerometer are transferred into the vibration controller. The amplified signal is then transferred to the vibrator, causing its excitation.

The vibration was applied by the control signal through the power amplifier controlled by the output signal from the accelerometer, thereby maintaining the acceleration at 1.0 meter per square second (m/s2). A vibration-imposed system consists of a vibration controller, charge amplifier, vibrator, force sensor and accelerometer. The top of the vibrator is fixed on the tooth with an adhesive. The vibration tests were carried out for 5 minutes, and the resonance curves were displayed as frequency-force relationships on the monitor of the vibration controller. Clinical trials were conducted by various researchers on human population using oral vibrating devices such as Accledent TM, Accele Dent® and electric tooth brushes and found to be effective in increasing the rate of tooth movement.

Fig. 8. Acceledent

Periodontal Distraction: Distraction osteogenesis was used as early as 1905 by Codivillaand was later popularized by the clinical and research studies of Ilizarov (1988) in Russia. A horizontal mucosal incision was made parallel to the gingival margin of the canine and the premolar beyond the depth of the vestibule. Cortical holes were made in the alveolar bone with a small, round, carbide bur from the canine to the second premolar, curving apically to pass 3 to 5 mm from the apex. A thin, tapered, fissure bur was used to connect the holes around the root. Fine osteotomes were advanced in the coronal direction. The first premolar was extracted and the buccal bone removed between the outlined bone cut at the distal canine region anteriorly and the second premolar posteriorly. Larger osteotomes were used to fully mobilize the alveolar segment that included the canine by fracturing the surrounding spongious bone around its root off the lingual or palatal cortex. The buccal and apical bone through the extraction socket and the possible bony interferences at the buccal aspect that might be encountered during the distraction process were eliminated or smoothened between the canine and the second premolar, preserving palatal or lingual cortical shelves. The palatal shelf was preserved, but the apical bone near the sinus wall was removed, leaving the sinus membrane intact to avoid interferences during the active distraction process. Osteotomes along the anterior aspect of the canine were used to split the surrounding bone around its root from the palatal or lingual cortex and neighbouring teeth. The transport dentoalveolar segment that includes the canine also includes the buccal cortex and the underlying spongy bone that envelopes the canine root, leaving an intact lingual or palatine cortical plate and the bone around the apex of the canine. The incisionis closed with absorbable sutures, and an antibiotic and a nonsteroidal anti-inflammatory drug is prescribed for five days.

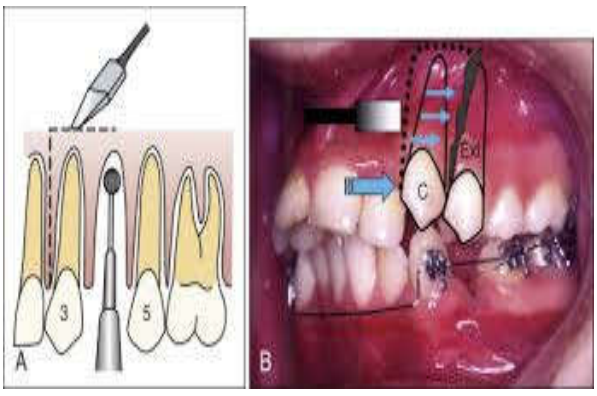


Fig. 9. Periodontal Distraction

Electromagnetic fields: Electromagnetic fields have a proven effect on cell membrane permeability.3 They can be divided into static magnetic fields (SMF) and pulsed electromagnetic fields (PEMF). Both types have been used in general medicine for many years. A SMF can contribute to the healing process after an osteotomy, can stimulate bone remodelling, or prevent bone volume decrease after surgical intervention or implantation. In the field of orthodontics, it has been used for many years as an element supporting active therapy or even as an independent procedure. It may be of certain clinical benefit during space closure, intrusion, forced extrusion of impacted teeth, and palatal expansion. An analysis of the few available animal studies concludes that in order to accelerate tooth movement, a field with a flux density of 460 mT should be used. Sakata et al. came to this conclusion analysing the previous experiment of Tangka et al., who, while using the intensity of 10 mT, did not observe clinically satisfactory results.

A PEMF, by stimulating osteoblasts to proliferate and differentiate, as well as increasing the production of alkaline phosphatase and regulating calcium metabolism, can improve the treatment of bone fractures, osteonecrosis and osteoporosis, among other things. According to Bassett's research, therapeutic application of magnetic fields results in the creation of cellular tension similar to that which is induced during mechanical deformation of the bone (e.g., during the movement of the teeth).Studies on a rat model have shown that the support of active orthodontic elements operating with a force of about 20 g, both using a PEMF of 1.8 mT (or 1.5 mT) and a Nd-Fe-B magnet (neodymium), increases the distance a tooth can be moved. Stark and Sinclair and Showkatbakhsh et al. also confirmed the accelerating action of PEMF.

The clinical trial by Showkatbakhsh et al., assessed the distalization of the canine after 1st premolar extraction, using a removable PEMF-generating device with an intensity of 0.5 mT and a frequency of 1 Hz.49 After 6 months, the difference in movements between the test and control groups was 1.57 ±0.83 mm. Dogru et al. performed an experiment on rats comparing a PEMF to a sinusoidal field. In both cases, they observed positive effects. However, the authors pointed out that due to differences in size and physiology, predicted results on the human body should be extrapolated with caution. Information regarding the lag phase in orthodontic tooth movement (the phase of clearing hyalinized fibres from the pressurezone) is also important. It can be hypothesized that electromagnetic field therapy can shorten the lag phase (due, among other things, to earlier formation and removal of hyalinized tissue).

Surgical Techniques

Principle: Direct injury to the both alveolar bones (maxillary arch and mandibular arch) AOTM by inducing regional acceleratory phenomenon (RAP), as a wound-healing process, which is the basis for clinical procedures such as corticotomy-assisted orthodontics, piezocision-aided orthodontics, and surgery-first orthodontics. Bichlmayr introduced a surgical technique for rectification

of severe maxillary protrusion with available orthodontic appliances. Wedges of alveolar bone were removed to decrease the volume of the bone through the radicular parts of the maxillary teeth in anterior region. Kolesuggested a technique of creating bony blocks (bone-teeth unit) through the corticotomy to enhance the faster tooth movement. For the next fifty years this concept prevailed until Wilcko and co-workers reported atransient demineralization - remineralization procedure enchanting after corticotomy, which was termed as aperiodontally accelerated osteogenic orthodontics (PAOO).

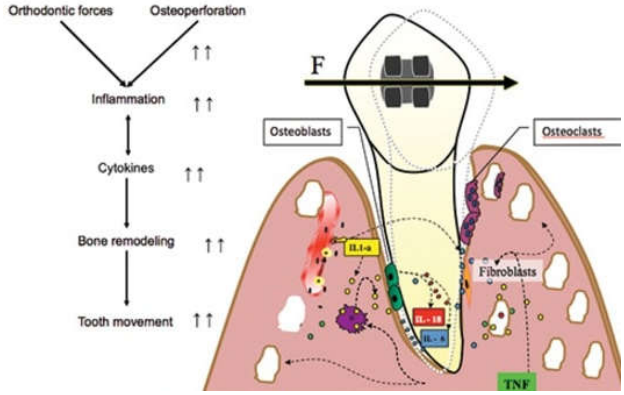


Fig. 10. Effects of Surgical Techniques

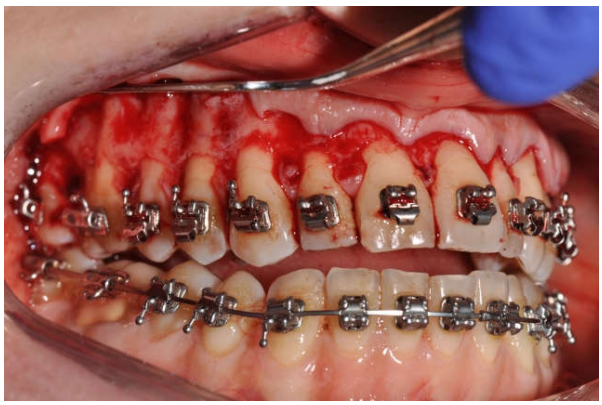


Fig 11: Diodontids

Fig. 12. Piezocision

The PAOO is an amalgamation of selective decortications and facilitated orthodontic techniques along with alveolar augmentation. This procedure increases the alveolar bone volume after orthodontic treatment by using bone grafts consists of decalcified freeze-dried bone allograft (DFDBA).

This technique decreases the treatment time to 33% the time of conventional treatment duration in orthodontics. This concept was based on a similar technique, which was described as regional acceleratory phenomena (RAP) earlier. This method is a local response to a lethal stimulus that describes a process of tissue formation faster than the usual local regeneration process. Enhancing a variety of healing stages, this RAP makes healing occur 2-10 times earlier than regular healing . However, this is an old technique and very invasive hence, this was accepted by all patients. Hence, latest procedures like corticision, piezosurgery, fiberotomy and microosteoperforations had demonstrated. Bone is surgically wounded so as to initiate a localized inflammatory response. The presence of cytokines andchemokines through prostaglandin E2 pathway and the RANK/RANKL pathway causes differentiation of osteoclasts which leads to bone resorption and thus AOTM is possible. It has been reported that this effect lasts for 4 months and this method needs to be repeated, in case faster tooth movement in further if required.

The techniques used mainly are:

Corticotomy: The conventional corticotomy procedure involves elevation of full thickness mucoperiosteal flaps, buccally and/or lingually, followed by placing the corticotomy cuts using either micro motor under irrigation, or piezosurgical instruments. This can be followed by placement of a graft material, wherever required, to augment thickness of bone. In 2001, Wilckoetal reported that a surface-computed tomographic evaluation of corticotomized patients clearly showed a transient localized demineralization-remineralization process consistent with the accelerated wound-healing pattern of the regional acceleratory phenomenon.

Advantages

- It has been proven successfully by many authors, to accelerate tooth movement.
- Bone can be augmented, thereby preventing periodontal defects, which might arise, as a result of thin alveolar bone.

Disadvantages

- High morbidity associated with the procedure.
- Invasive procedure.
- Chances of damage to adjacent vital structures.
- Post-operative pain, swelling, chances of infection,
- a vascular necrosis.
- Low acceptance by the patient.

Park et al in 2006, and Kim et al in 2009, introduced the corticison technique, as a minimally invasive alternative to surgically injure the bone without flap elevation.

Piezocision: To reduce the morbidity associated with conventional corticotomy, Dibart et al in 2009, introduced a flapless method of corticotomy, using piezosurgery. In the technique described by them, the surgery was performed 1 week after placement of orthodontic appliance, under local anaesthesia. Gingival vertical incisions, only buccally, were made below the interdental papilla, as far as possible, in the attached gingiva using a No.15 scalpel. These incisions need to be deep enough so as to pass through the periosteum, and

contact the cortical bone. Next, using ultrasonic instrumentation (they used a BS1 insert Piezotome), to perform the corticotomy cuts to a depth of 3 mm through the previously made incisions. At the areas requiring bone augmentation, tunnelling is performed using an elevator inserted between the incisions, to create sufficient space to accept a graft material. No suturing is required, except for the areas, where the graft material needs to be stabilized. Patient is placed on an antibiotic, mouthwash regimen.

Advantages

- Minimally invasive.
- Better patient acceptance.

Disadvantages

- Risk of root damage, as incisions and corticotomiesare "blindly" done.
- To reduce the risk of root damage, however, Jorge et al in 2013,14 suggested a method, called MIRO (Minimally Invasive Rapid Orthodontic procedure) by using metal wire as a guide to placement of the incisions, and subsequently the corticotomy cuts. He placed metal guides in between each tooth, perpendicular to the main arch wire, and took digital radiographs, to ensure that the metal guides did not project over the tooth roots. Once this was confirmed, incisions and piezoelectric corticotomy was done using the pins asa guide.

Surgery first approach: Surgery-first orthodontics is a strategy to significantly shorten treatment duration for patients who need orthognathic surgery to correct a severe dentofacial deformity. Traditional comprehensive orthodontic orthognathic surgery treatment starts with orthodontic treatment to align the teeth and decompensate the dentition to prepare for optimum correction of skeletal discrepancies. After surgery, orthodontic treatment is needed to settle the occlusion and refine the finishing. Typically, the total treatment time is about 24 to 30 months. Studies have shown that tooth movement after orthognathic surgery is much faster than with routine orthodontic treatment, which can be attributed to RAP stimulated by the surgical wound to the bone. Careful patient selection is required to perform surgery-first orthodontics and should follow certain guidelines and procedures.

Conclusion

Fixed orthodontics could last for 24 to 36 months which further poses the risk of complications associated with the treatment such as external root resorption, periodontal problems and patient compliance. Orthodontists are persistently motivated towards developing potential strategies to enhance the rate of orthodontic tooth movement.

REFERENCES

Alikhani M, Raptis M, Zoldan B, et al., 2013. Effect of micro-osteoperforationson the rate of tooth movement. *Am J Orthod Dentofacial Orthop.,*144:639–648.

Al-Sayed Hasan MMA, Sultan K, Hamadah O. 2017. Low-level laser therapy effectiveness in accelerating orthodontic tooth movement: A randomizedcontrolled clinical trial. *Angle Orthod.,* 87:499–504.

Bassett CA. Beneficial effects of electromagnetic fields. J Cell Biochem.1993;51:387–393.

Cao H., Kou X., Yang R. et al., 2014. Force-induced Adrb2 in periodontalligament cells promotes tooth movement. *J Dent Res.,* 93:1163–1169.

Charavet C, Lecloux G, Bruwier A, et al., 2016. Localized piezoelectric alveolardecortication for orthodontic treatment in adults: A randomizedcontrolled trial. *J Dent Res., 9*5:1003–1009.

Darendeliler MA, Sinclair PM, Kusy RP. The effects of samariumcobaltmagnets and pulsed electromagnetic fields on tooth movement. *Am J Orthod Dentofacial Orthop*. 1995;107:578–588.

Darendeliler MA, Zea A, Shen G, Zoellner H. Effects of pulsed electromagneticfield vibration on tooth movement induced by magneticand mechanical forces: A preliminary study. Aust Dent J.2007;52:282–287.

Dibart S., Keser EI., 2014. Piezocision™. In: Brugnami F, Caiazzo A, eds. Orthodontically Driven Corticotomy: Tissue Engineering to Enhance Orthodontic and Multidisciplinary Treatment. Hoboken, NJ: JohnWiley & Sons.

Dubravko P, Ravikumar A, Vishnu R, Gakunga PT. Cyclic loading (vibration) accelerates tooth movement in orthodontic patients: A doubleblind, randomized controlled trial. Semin Orthod. 2015;21:187–194.doi: 10.1053/j.sodo.2015.06.005

Fitzsimmons RJ, Ryaby JT, Magee FP, Baylink DJ. Combined magneticfields increased net calcium flux in bone cells. Calcif Tissue Int.1994;55:376–380.

Frost MH. 1989. The biology of fracture healing: An overview for clinicians. Part I. *ClinOrthop Relat Res.,* 248:283–293.

Hwang HS, Lee KH. 2001. Intrusion of over erupted molars by corticotomyand magnets. *Am J Orthod Dentofacial Orthop.,* 120:209–216.

Kacprzak, A. Strzecki. A. Accelerating orthodontic treatment: A review

Kale S, Kocadereli I, Atilla P, Aşan E. 2004. Comparison of the effectsof 1,25 dihydroxycholecalciferol and prostaglandin E2 on orthodontictooth movement. *Am J Orthod Dentofacial Orthop.*, 125:607–614.

Kawasaki K, Shimizu N. 2000. Effects of low-energy laser irradiation onbone remodeling during experimental tooth movement in ratsLasers Surg Med., 26:282–291.

Kim SJ, Park YG, Kang SG. 2009. Effects of Corticision on paradentalremodeling in orthodontic tooth movement. *Angle Orthod.,* 79:284–291.

Kim YD, Kim SS, Kim SJ, Kwon DW, Jeon ES, Son WS. 2010. Low-level laser irradiation facilitates fibronectin and collagen type I turnover duringtooth movement in rats. *Lasers Med Sci.,* 25:25–31.

Köle H. 1959. Surgical operations of the alveolar ridge to correct occlusalabnormalities. *Oral Surg Oral Med Oral Pathol.,* 12:515–529.

Kondo M., Kondo H., Miyazawa K., Goto S., Togari A. 2013. Experimental tooth movement-induced osteoclast activation is regulated bysympathetic signaling. Bone. 52:39–47.

Kotani H, Kawaguchi H, Shimoaka T, et al., 2002. Strong static magnetic field stimulates bone formation to a definite orientation in vitroand in vivo. *J Bone Miner Res.,* 17:1814–1821.

Landry PS, Sadasivan KK, Marino AA, Albright JA. 1997. Electromagnetic fields can affect osteogenesis by

increasing the rate of differentiation. *Clin Orthop Relat Res.*, 338:262–270.Dent Med Probl. 2018;55(2):197–206 205

Lee JK, Chung KR, Baek SH. 2007. Treatment outcomes of orthodontitreatment, corticotomy-assisted orthodontic treatment, and anterior segmental osteotomy for bimaxillary dentoalveolar protrusion. *Plast Reconstr Surg.*, 120:1027–1036.

Leethanakul C, Suamphan S, Jitpukdeebodintra S, Thongudomporn U, Charoemratrote C. Vibratory stimulation increases interleukin-1beta secretion during orthodontic tooth movement. Angle Orthod.2016;86:74–80.

Li F, Li G, Hu H, Liu R, Chen J, Zou S. 2013. Effect of parathyroid hormone on experimental tooth movement in rats. *Am J Orthod Dentofacial Orthop*., 144:523–532.

Marcus R. 1997. Skeletal effects of growth hormone and IGF-I in adults. Horm Res. 48(Suppl 5):60–64.

Marquezan M, Bolognese AM, Araújo MT. 2010. Effects of two low-intensitylaser therapy protocols on experimental tooth movement. *Photomed Laser Surg.,* 28:757–762.

Miles P, Fisher E, Pandis N. Assessment of the rate of premolar extractionspace closure in the maxillary arch with the AcceleDent Auraappliance vs no appliance in adolescents: A single-blind randomizedclinical trial. Am J Orthod Dentofacial Orthop. 2018;153:8–14.

Murphy KG, Wilcko MT, Wilcko WM, Ferguson DJ. 2009. Periodontal acceleratedosteogenic orthodontics: A description of the surgical technique. *J Oral Maxillofac Surg.,* 67:2160–2166.

Nahas AZ, Samara SA, Rastegar-Lari TA. 2017. Decrowding of lower anterior segment with and without photobiomodulation: A single center,randomized clinical trial. *Lasers Med Sci.,* 32:129–135.

Nishimura M, Chiba M, Ohashi T, et al. Periodontal tissue activationby vibration: Intermittent stimulation by resonance vibration accelerates experimental tooth movement in rats. Am J Orthod Dentofacial Orthop. 2008;133:572–583.

Proffit WR, Fields HW, Sarver DM. The biologic basis of orthodontic therapy. In: Komorowska A, ed. Contemporary Orthodontics [in Polish]. Wrocław,

Reichel H, Koeffler HP, Norman AW. 1989. The role of the vitamin D endocrinesystem in health and disease. *N Engl J Med.,* 320:980–991.

Ren Y, Vissink A. Cytokines in crevicular fluid and orthodontic tooth movement. Eur J Oral Sci. 2008;116:89–97.

Ribeiro JS, Maciel JV, Knop LA, Machado MÂ, Grégio AM, Camargo ES. 2013. Effect of growth hormone in experimental tooth movement. *Braz Dent J.,* 24:503–507.

Sanjideh PA, Rossouw PE, Campbell PM, Opperman LA, Buschang PH. 2010. Tooth movements in foxhounds after one or two alveolar corticotomies. *Eur J Orthod.,* 32:106–113.

Sebaoun JD, Kantarci A, Turner JW, Carvalho RS, Van Dyke TE,Ferguson DJ. 2008. Modeling of trabecular bone and lamina dura following selective alveolar decortication in rats. *J Periodontol.,* 79:1679–1688.

Showkatbakhsh R, Jamilian A, Showkatbakhsh M. The effectof pulsed electromagnetic fields on the acceleration of toothmovement. *World J Orthod*. 2010;11:52–56.

Soma S, Matsumoto S, Higuchi Y, et al., 2000. Local and chronic application of PTH accelerates tooth movement in rats. *J Dent Res.,* 79:1717–1724.

Szymańska-Kubal D. 1999. Selected complications of orthodontic treatment with fixed and removable appliances [in Polish]. NowaStomatol. 4:1–2:31–40.

Takeda S., Elefteriou F., Levasseur R. et al., 2002. Leptin regulates bone formationvia the sympathetic nervous system. Cell.111:305–317.

Takeuchi T., Tsuboi T., Arai M., Togari A. 2001. Adrenergic stimulation of osteoclastogenesis mediated by expression of osteoclast differentiation factor in MC3T3-E1 osteoblast-like cells. *Biochem Pharmacol.* 61:579–586.

Teixeira CC, Khoo E, Tran J, et al. Cytokine expression and acceleratedtooth movement. J Dent Res. 2010;89:1135–1141.

Tsichlaki A, Chin SY, Pandis N, Fleming PS. 2016. How long does treatment with fixed orthodontic appliances last? A systematic review. *Am J Orthod Dentofacial Orthop*., 149:308–318.

Üretürk SE, Saraç M, Fıratlı S, Can ŞB, Güven Y, Fıratlı E. 2017. The effectof low-level laser therapy on tooth movement during canine distalization. *Lasers Med Sci.,* 32:757–764.

Vander Molen MA, Donahue HJ, Rubin CT, McLeod KJ. 2000. Osteoblasticnetworks with deficient coupling: Differential effects of magneticand electric field exposure. Bone. 27:227–231.

Wilcko MT., Wilko WM., Bissada NF., 2008. An evidence-based analysis of periodontallyaccelerated orthodontic and osteogenic techniques: A synthesisof scientific perspective. *Semin Orthodont*., 14:305–316.

Wilcko WM., Wilcko MT., Bouquot JE., Ferguson DJ. 2000. Accelerated orthodonticswith alveolar reshaping. J Ortho Practice.10:63–70.

Wilcko WM., Wilcko T, Bouquot JE, Ferguson DJ. 2001. Rapid orthodonticswith alveolar reshaping: Two case reports of decrowding. *Int J PeriodonticsRestorative Dent.,* 21:9–19.

Woodhouse NR, DiBiase AT, Johnson N, et al. Supplemental vibrationalforce during orthodontic alignment: A randomized trial.J Dent Res. 2015;94:682–689.

Yadav S, Dobie T, Assefnia A, Gupta H, Kalajzic Z, Nanda R. Effectof low-frequency mechanical vibration on orthodontic toothmovement. Am J Orthod Dentofacial Orthop. 2015;148:440–449.

Yaffe A, Fine N, Binderman I. 1994. Regional accelerated phenomenon inthe mandible following mucoperiosteal flap surgery. *J Periodontol*., 65:79–83.

Youssef M, Ashkar S, Hamade E, Gutknecht N, Lampert F, Mir M. 2008. The effect of low-level laser therapy during orthodontic movement: A preliminary study. Lasers Med Sci., 23:27–33.

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